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Wednesday, November 08, 2006

A raw idea to avoid being cooked

I come up with far more ideas than I have time to properly evaluate, much less pursue. Long ago I worked at the Jet Propulsion Laboratory and I still occasionally daydream about space stuff. Recently there have been several proposals for shading the earth from the sun, put forth to combat global warming. I've been noodling on my own sunshade idea for several years. For your entertainment (and who knows, it might also turn out to be quite useful) here it is:

Put a bunch of Venetian blinds at a spot permanently between the earth and the sun (know to orbital engineers as the first earth-sun Lagrange point, a.k.a. "L1"). These blinds would be refractive rather than reflective to minimize the stationkeeping needed to prevent being "blown" away by the pressure of sunlight. At L1 they only need to refract the light by less than one degree of angle for the light to miss the earth. Less than 2% of sunlight needs to be deflected away from earth to offset the expected global warming from "greenhouse gases," primarily carbon dioxide.

Venetian blinds, unlike this proposal, and this one, can be opened or closed to allow continued control over the amount of sunlight hitting earth. This is essential since we can't really predict with great accuracy the degrees of global warming that we will need to combat. The blinds I propose, rather than being a number of joined slats as in a normal Venetian blind, are simply a large number of separate satellites each with a refractive slat that can be manuevered to any angle with the sun (i.e. from fully "closed" vertical to fully "open" horizontal).

I propose that the blinds be placed precisely at the region where they will deflect primarily light headed for equatorial regions on earth. That will even out temperatures a bit between northern and equatorial latitudes and reduce the energy (caused by temperature differences) available for storm formation, and thus probably the intensity of storms (although the effect, like the effect of global warming itself, on storms may be negligible). But the blinds should be maneuverable enough, by using solar electric propulsion or "sailing" on sunlight pressure, to redeploy to deflect sunlight headed to extreme latitudes if polar ice sheet melting becomes a larger problem than equatorial heat.

Instead of launching these vast (or vast number of) panels from the very deep gravity well of earth or manufacturing them on the moon (which probably lacks the proper organic ingredients and even sufficient water, a crucial industrial input), we can extract the raw materials from any near-earth asteroids containing water and methane ice or, if there are none such, from Jupiter-family comets. Besides the proper raw materials being available in sufficient volume in such ice, but probably not on the moon, there are a number of other advantages to microgravity ice mining explained in that linked article. If extracting material from comets and manufacturing the blinds can be automated the entire vast project can be conducted by launching just a few dozen of today's rockets using the recently-

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Nick Szabo

"A premier thinker about history, law and economics, and the lessons they have for security." -- Adam Shostack, Emergent Chaos

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proven solar electric upper stages; otherwise it will require manned missions similar to those recently proposed to Mars, but again using solar-electric upper stages. (Solar electric rockets are only required for the first trip; much lower cost solar-thermal ice rockets can be used in subsequent trips, again as explained in that linked article).

Of course shades don't combat other effects of excess carbon dioxide such as ocean acidification and faster and differential plant growth, but these effects alone do not justify the vast costs of reducing carbon dioxide emissions. Indeed faster plant growth is probably a major economic benefit.

My off-the-cuff estimate of cost, which is probably as good as any recent NASA estimate for any of their gigaprojects, is that the project would cost $10 billion per year over 50 years. That's for the manned version; if it could be automated it would cost far less. This is far cheaper than other space-based sunshade proposals because once initial capital costs are made and the first two or three bootstrapping cycles have been undertaken, the ongoing transport costs of material from comet to the earth-sun L1 point are extremely small.

As a side benefit it would (unlike a mission to the moon or Mars or a "base" or any similar project) develop infrastructure needed for large-scale space industry and colonization. I propose funding the project, not with a tax, but by treating the blinds like a carbon dioxide sink and auctioning extra carbon dioxide credits for a global carbon dioxide market, since the shade allows us to be far less drastic in reducing growth of carbon dioxide emissions. If instead of a market we go with carbon taxes the project could be funded from those. $10 billion per year is much lower than even the most optimistic estimates (at 1% of world GDP about $500 billion per year) of the costs of reducing carbon dioxide emissions. Furthermore, there are a variety of other markets for large-scale industry that can be exploited once the basic ice mining infrastructure is developed: space tourism and making manned missions and other transportation around the solar system vastly less expensive, for starters, as well as providing propellant, tankage, and industrial raw materials in earth orbits. As I stated in 1994:

> If the output of the icemaking equipment is high, even 10% of the original mass [returned to earth orbit by rockets using water propellant extracted from the comet ice] can be orders of magnitude cheaper than launching stuff from Earth. This allows bootstrapping: the cheap ice can be used to propel more equipment out to the comets, which can return more ice to Earth orbit, etc. Today the cost of propellant in Clarke [geosynchronous] orbit, the most important commercial orbit, is fifty thousand dollars per kilogram. The first native ice mission might reduce this to a hundred dollars, and to a few cents after two or three bootstrapping cycles.

The savings for transporting materials to the earth-sun L1 point, instead of launching them from earth, are even larger.

Posted by Nick Szabo at 10:11 PM

12 comments:

Brian Dunbar said...

I recall that one consequence of a massive deployment of space-based SDI assets would be that we'd have just huge fleet of shops (rockets, space planes, whatever) used for deploying the 'Star Wars' satellites and of course those would be useful for cutting the cost of civilian space flight down.

A space shade can be seen in the same light.

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8:43 AM

Paul Szabo said...

so if current climate models turn out to be wrong and we head into another ice age, can you design and maneuver the panels so as to add additional sunlight?

11:58 PM

Nick Szabo said...

Brian, I think it's much better than SDI might have been in that regard, since it develops an infrastructure that vastly reduces transport costs beyondy earth orbit as well as the cost of many industrial raw materials such as water and various organics. It enables quite a number of new activities, including affordable interplanetary space tourism, asteroid mining (for platinum etc.) and microgravity industry with inexpensive inputs. These activities won't much look like the traditional NASA and Russian space programs.

My answer to Paul's question is another example. The blinds can't increase sunlight to the earth beyond the natural level just by moving them to the other side of the earth, because they are somwhat irregularly refractive, not regularly reflective. But the same technology that transports raw materials and most of the technology that manufactures the blinds can be used to make regularly reflective mirrors to warm the earth up, should Paul's scenario occur.

Furthermore, similar mirror technology can be used to warm up Mars if we so wish, to melt asteroids, and provide extra illumination at most places in the outer solar system where sombody might want to set up shop.

8:52 AM

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8:53 AM

Daniel A. Nagy said...

My gut feeling is that L1 is just too far away for being in the way of a significant proportion sunrays we receive and thus for a reasonable amount of blinds to make a difference. The Sun is not a point source (it's approx 0.5 degrees across), so distance matters.
Is there any significant cooling effect from the occasional solar eclipses caused by the Moon?
I think that the proportion of time in which there's a Moon shadow on Earth is far larger than the proportion of sunrays blocked (or diverted) by such blinds to those blocked by the Moon.
I'll do some back-of-the-envelope calculations soon.

5:17 PM

Daniel A. Nagy said...

Here are the promised numbers:
L1 is roughly 1/100 of the way towards the Sun. The radius of the Sun is roughly $7 \cdot 10^8$m, thus its cross-section is $1.5 \cdot 10^{18}$m^2.
Hence, the minimal surface area of a disk that would totally eclipse the Sun at L1 is $1.5 \cdot 10^{14}$m^2. The total area of blinds to eclipse 2% thereof would be $3 \cdot 10^{12}$m^2 or about 1% of Earth's total surface or about one third of the total area of the United States.
Their shadow will spread pretty much all over Earth (remember, the Sun is *not* a point source); there is no way to concentrate it on equatorial regions.

4:14 AM

Graham Asher said...

Anything that can shade large parts of the earth or deflect sunlight will be seen as at worst a weapon or at best a political tool for rewarding or punishing. It can make half the world poorer or richer at a stroke. Power like that can only be controlled by a world government, which is not necessarily a good thing. Any attempt to deploy the system unilaterally would inevitably be seen as a casus belli by one or more other powers. Apart from that it's a great idea.

3:56 PM

Nick Szabo said...

Daniel, you may be right that one can't much control which part of earth one is shading. I was getting quite raw at that point of my account when I suggested you could substantially shade the poles but not the the equator or vice versa. :-) I'll have to go re-check that part of my optics research. The rest of my optics can be verified by reading at least one of the other proposals (e.g. that of Roger Angel) that also uses refraction instead of reflection.

The vast area we need to cover, and thus the vast mass and bulk of the structures, is why it makes much more sense to manufacture and transport the blinds using cheap native materials and transport in a low-power microgravity regime instead of launching them from deep gravity well of earth. Also the material is important: organics, but not glass, can be made gossamer-thin which means you can use as raw materials ice, from comets or (if possible) asteroids, rather than making glass from the moon as another proposal does. (Even with glass transport costs are much lower if the glass is made from a near-earth asteroid than lunar material).

Graham, you raise an interesting point about the strategic importance of the Earth-Sun L1. Legally it's a natural monopoly of the kind that would have been called a "franchise" under old English common law -- like owning the only bridge across a river. (In the U.S. at least we still call cable and water company local monopolies "franchises"). Legally
since nobody can compete with a natural monopoly, a franchise had to sell at a reasonable price and provide service to all customers willing to pay that price. A reasonable price here would be some thermal equivalent to carbon dioxide emission rights sold on a market, or a similar share of a carbon tax. Reasonable service has to include not shading the earth more or less than what the sold carbon rights imply, i.e. not more or less than to make up for the extra carbon dioxide emissions that can be compensated for by the shading. If there's already an earthsiinde carbon dioxide emissions market that allows for carbon dioxide sinks to issue extra rights, "reasonable price" issue is simply one of determining the equivalent in carbon dioxide units, then selling the extra rights on the existing market.

Earth-Sun L1 is a strategic chokepoint for the earth's sunlight, somewhat like Gibraltar for the Atlantic-Mediterranean sea trade or Malacca for the China-India trade. Recall that historically Portugal gained about a century in the sun as the first worldwide empire by taking control of these two strategic points.

This raises the twin military issues of (1) how to protect this legal regime from terrorism, extortion, or other threats, including (2) how to protect the legal regime from said military itself. This, as they say in math textbooks, is left as an exercise for the student. :-)

11:40 PM

Joel said...

"glass can[not] be made gossamer-thin"

Uh...has anyone else here heard of fiber glass? Or maybe fiber optics?

A gauze with much thinner fibers and a little denser weave than the type used to reinforce joints in bathroom wallboard would work pretty well. The redirection of light from this would be partly refractive, but mostly diffractive.

But glass isn't the material I'd choose: I'd go for basalt. Basalt fibers are stronger, and can be made from rock directly.

Glass might be a good substrate for very large thin-film solar cells, if cooling can be managed. Having that much power in space, to be transmitted e.g. by microwave, may be enough reason in itself to set up a large L1 station.

11:56 PM

Nick Szabo said...

Joel, it's an interesting approach but I'm quite skeptical that one can make micron-thin textiles with sufficient tear resistance and the proper optical properties purely using lunar materials. It has to be tear resistant to be launched in a high-g regime from the moon and then be unfolded and assembled.

"Fiberglass" used in textile-like materials AFAIK is a composite of glass fibers and organic polymers. If somebody knows of a reasonably cohesive, strong, and gossamer-thin textile made purely of glass or basalt fibers I'd love to be pointed to the specifics. And by "gossamer-thin" I mean that the textile itself is microns thick, not just the fiber. If it has to be 100 microns rather than 10 microns thick that increases the mass required by a factor of a ten. And that's before factoring in that glass and basalt are much denser than Kapton, Mylar, or similar organic materials.

Even if one can make good blinds of pure glass or basalt I'm also skeptical about the ability to manufacture them without extensive volatile inputs which are probably much too scarce on the moon. The glass is heated above 1200C (basalt 1400C) and one needs a way to cool the glass very quickly so that it will form the proper amporphous structure. One also needs to cool the machinery. These are tasks for large amounts of air (not pure oxygen, please!) or liquids. Ingredients for good coolant are probably not available in sufficient quantities on the moon. Air is also often used in other parts of the manufacturing process, such as air jets used to form fibers into a mat. To get air that is not very chemically reactive (e.g. nitrogen) you'd have to go to the comet or asteroid ice anyway: hauling such vast quantities from earth is almost surely far too expensive.

9:36 AM

Brian Dunbar said...

hauling such vast quantities from earth is almost surely far too expensive.

This is true now. It will not always be so. Some of us have ideas along that line actually .. but you know this.

4:23 PM

Nick Szabo said...

Brian, I'm sure you know much more about the Space Elevator than I. Feel free to let us know!

Although a space elevator may provide a nice alternative to manufacturing the shade in space, there may be synergy as well. A full elevator would be centered at geosynchronous orbit. It will be (at least before the elevator itself is built) much cheaper, give the

infrastructure I have outlined, to get material to geosynchronous orbit from comets and asteroids than from the earth's surface via rocket. And methane ice might make a quite reasonable raw material for carbon nanotube tethers, or at the very least for the counterweight.

If the main limit on the manufacturing costs of carbon nanotube is energy costs, I have an idea for that too. (It won't solve energy problems on earth, though). A post for another day.

11:14 PM

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